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AUTHORS: Strakhovich, K. I., Sokovishin, Yu. A.

TITLE: Discharge of a laminar jet of conductive gas into a magnetic field

PERIODICAL: Inzhenerno-fizicheskiy zhurnal, v. 5, no. 10, 1962, 65 - 69

TEXT: This is studied by the methods of laminar boundary layers and jet streams. The gas jet is assumed to be discharged from a narrow slit of infinite length and to flow into the same gas kept at a constant pressure. γ, σ and μ are constant. Thermal effects and gas ionization are neglected. The equation of motion

$$\left.\begin{aligned} &\bar u \frac{\partial \bar u}{\partial \bar x} + \bar v \frac{\partial \bar u}{\partial \bar y} = \frac{\nu}{u_0 l}\frac{\partial^2 \bar u}{\partial \bar y^2} - \frac{\sigma\mu^2}{\rho u_0} l H_0^2 \bar u \bar H^2 \\ &\frac{\partial \bar u}{\partial \bar x} + \frac{\partial \bar v}{\partial \bar y} = 0, \quad \frac{\partial \bar H_x}{\partial \bar x} + \frac{\partial \bar H_y}{\partial \bar y} = 0 \\ &\frac{\partial \bar H_x}{\partial \bar y} = \frac{d\bar H}{d\bar x} - \sigma\mu u_0 l \bar u \bar H \end{aligned}\right| \qquad (3)$$

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Discharge of a laminar jet...

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of the gas in the reduced variables

$$\bar x = \frac{x}{l}, \quad \bar u = \frac{u}{u_0}, \quad \bar y = \frac{y}{l}, \quad \bar v = \frac{v}{u_0},$$

$$\bar H = \frac{H}{H_0}, \quad \bar H_y = \frac{H_y}{H_0}, \quad \bar H_x = \frac{H_x}{H_0}.$$

is transformed to the system

$$\frac{\partial \bar\psi}{\partial \bar y}\frac{\partial^2 \bar\psi}{\partial \bar x\,\partial \bar y} - \frac{\partial \bar\psi}{\partial \bar x}\frac{\partial^2 \bar\psi}{\partial \bar y^2} = \frac{1}{\mathrm{Re}}\frac{\partial^3 \bar\psi}{\partial \bar y^3} - N_0 \bar H^2 \frac{\partial \bar\psi}{\partial \bar y} \qquad (6),$$

$$\frac{\partial \bar H_x}{\partial \bar y} = \frac{d\bar H}{d\bar x} - \mathrm{Re}_M \bar H \frac{\partial \bar\psi}{\partial \bar y}, \qquad (7)$$

by introducing the dimensionless parameters

$$\mathrm{Re} = \frac{u_0 l}{\nu}, \quad \mathrm{Re}_M = \sigma\mu u_0 l, \quad N_0 = \frac{\sigma\mu^2}{\rho u_0} l H_0^2 \qquad (4)$$

and the dimensionless stream function $\bar\psi$. This system is solved with the following boundary conditions: (a) on the jet axis ($\bar y = 0$), $\bar v = 0$,
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$\partial\bar{u}/\partial\bar{y} = 0$, $\bar{H}_x = 0$; (b) if $\bar{y}\to\infty$, $\bar{u} = 0$; (c) at a great distance from the slit $\bar{H}_y = \bar{H} = 0$. From this system the principle of linear momentum $\bar{H}^2 x^{1+q-p} = \frac{ab}{N_0 f(\infty)} \int_0^\infty \left\{f'(\eta)\right\}^2 d\eta =$ const is derived. This equation is possible only if $\bar{H} = x^n$, where $n = (p-q-1)/2$. a, b, p and q are constants. On the condition that p = 0, q = 1, and n = -1 the solutions

$$\bar{u} = \frac{3}{2}\frac{N_0}{x}\left(1 - \mathrm{th}^2\frac{\eta}{2}\right) \qquad (17),$$

$$\bar{v} = \frac{3}{2}\sqrt{\frac{N_0}{\mathrm{Re}}}\frac{\eta}{x}\left(1 - \mathrm{th}^2\frac{\eta}{2}\right) \qquad (18)$$

are obtained for the velocity components,

$$\bar{H}_y = \frac{1}{x} - \frac{\eta}{x}\frac{1}{N_0\mathrm{Re}}\left(\eta + 3\mathrm{Re}_M N_0 \mathrm{th}\frac{\eta}{2}\right), \qquad (22) \text{ and}$$

$$\bar{H}_x = -\frac{1}{x}\frac{1}{\sqrt{N_0\mathrm{Re}}}\left(\eta + 3\mathrm{Re}_M N_0 \mathrm{th}\frac{\eta}{2}\right) \qquad (23)$$

for the components of the magnetic field and

$$Q = 2\rho\int_0^\infty u\,dy = 6\mu H_0\sqrt{\rho\nu\sigma} \qquad (19)$$

for the amount of fluid discharged per unit of time. At other values of n the equations of magnetohydrodynamics are not fulfilled.

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